ALS/APS Collaboration on 480 x 480 Fast CCD Detector

The APS story

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October 15-17, 2009

Outline

- Beamline Technical Support Group at APS
  (Slides from P. Fernandez)

- APS 480 x 480 Fast CCD Story
  - Milestones
  - Scientific Data (Slides from Dr. Larry Lurio from NIU)
  - Improvements
  - Detector Specifications
  - Future Tasks and Goals

- Future of Fast CCD Detectors at ANL
  - 1Kx1K Frame Transfer CCD

Advanced Photon Source Organization Chart
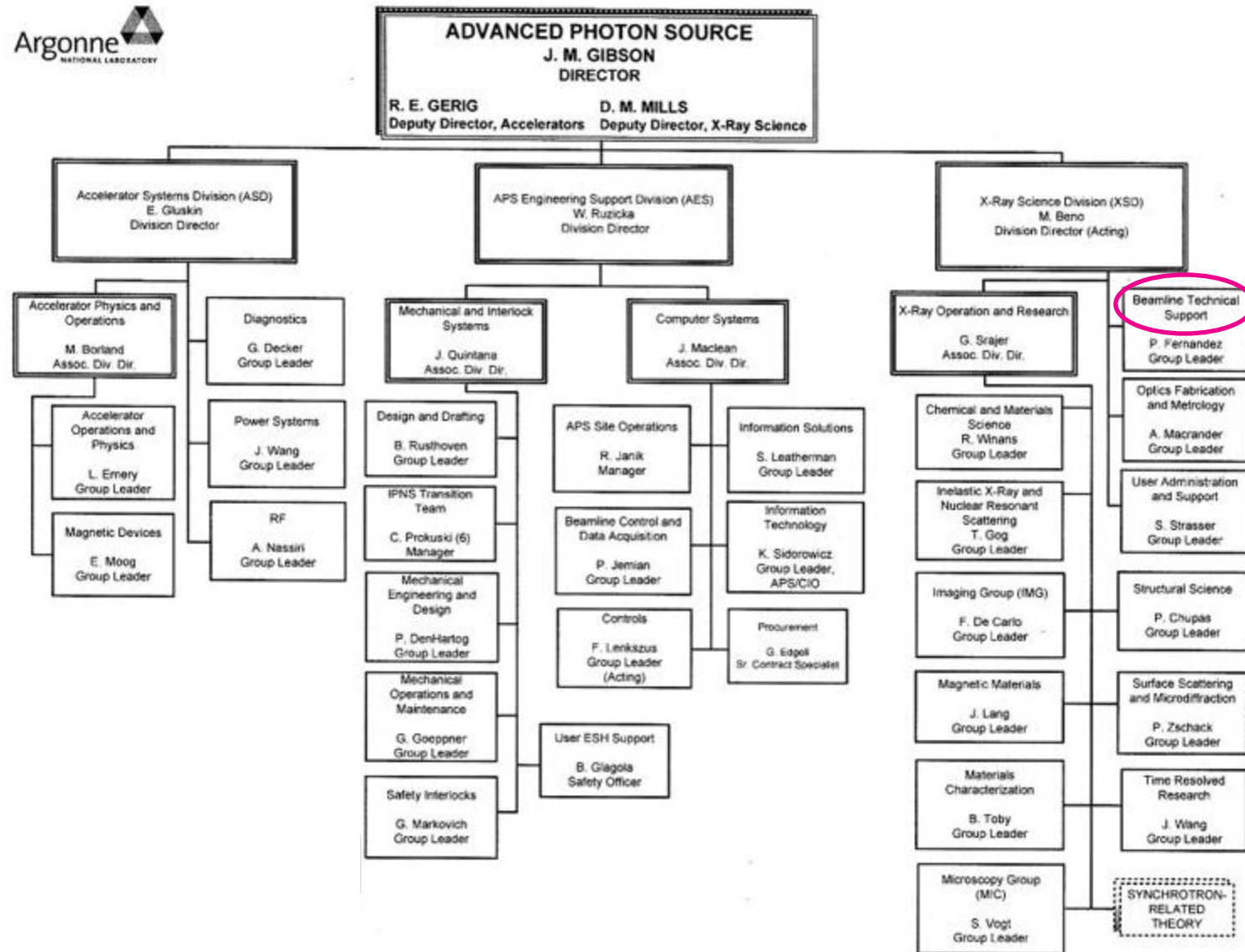
The XSD Beamline Technical Support Group

- Two main responsibilities
  - The APS Detector Pool
  - X-ray detector development

The APS Detector Pool

The goals of the Detector Pool are:

- To provide a range of detectors suitable for the research interests of the APS community.
- To provide expertise and guidance on x-ray detector capabilities and use.
- To identify and assess upcoming commercial technologies.
- Operate visible light and x-ray detector test stands, available to APS scientists.


APS Detector Pool – Contact: A. Miceli

XSD-BTS X-ray Detector R&D Activities

ALS/APS Collaboration on 480 x 480 fast CCD detectors

P. Denes, H. Padmore, ALS; J. Weizeorick, APS/XSD-BTS

- Produce two Fast CCD x-ray detectors using 480x480 pixels CCD chip, and six fCRIC readout chips

- At the APS, strong interest from the X-ray Photon Correlation Spectroscopy (XPCS) community

- BTS Personnel that worked on project
  - Jonathan Baldwin   - Kevin Beyer   - Lisa Gades   - John Lee
  - Troy Lutes   - Tim Madden   - Antonino Miceli   - Steve Ross
  - Chris Piatek
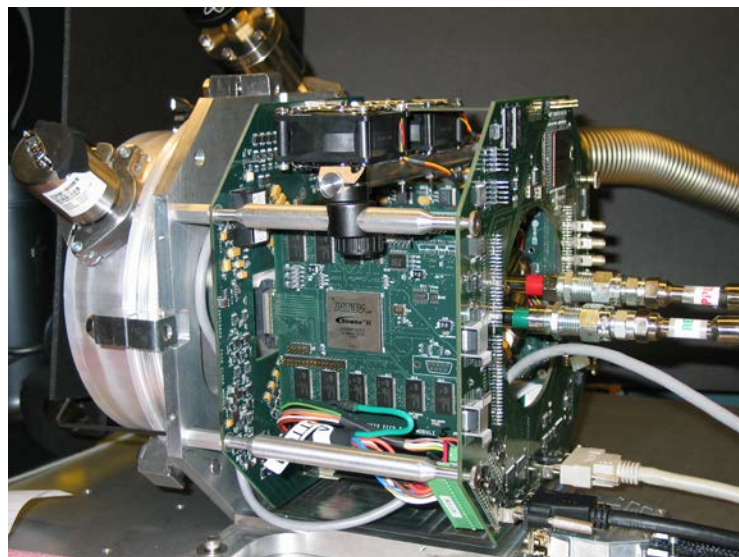
APS 480 x 480 Fast CCD Story – 2009 Milestones

APS 480 x 480 Fast CCD Story – 2009 Milestones
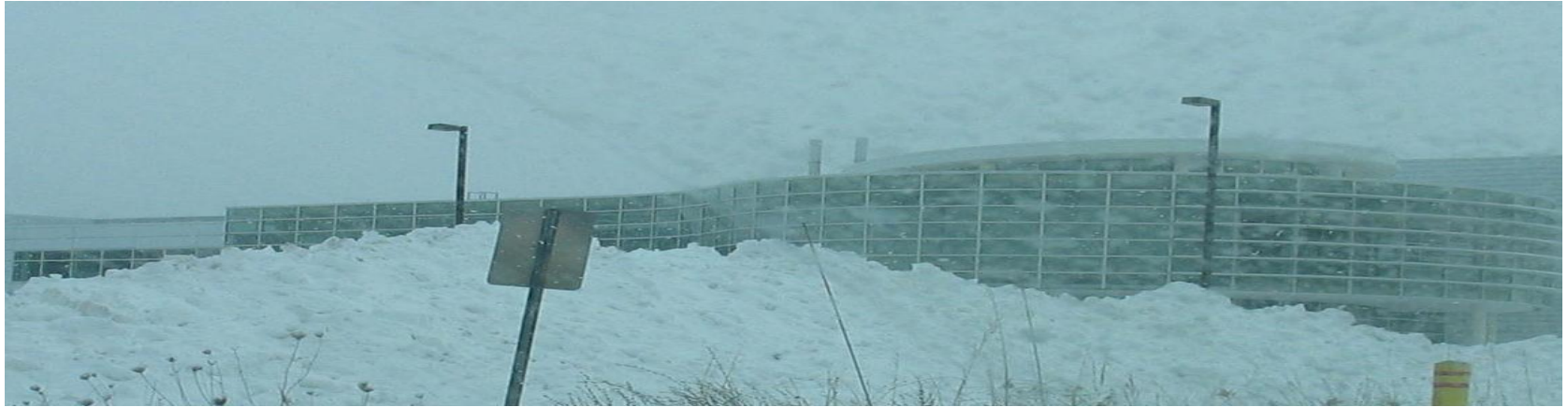
- January 11 – Peter and Dionisio arrived to install subassembly
- January 12 - First light with old substrate
- January 13 - First light with new substrate
- January 14 - First x-ray with x-ray tube
- January to July
  - Make Improvements
  - Characterize detector
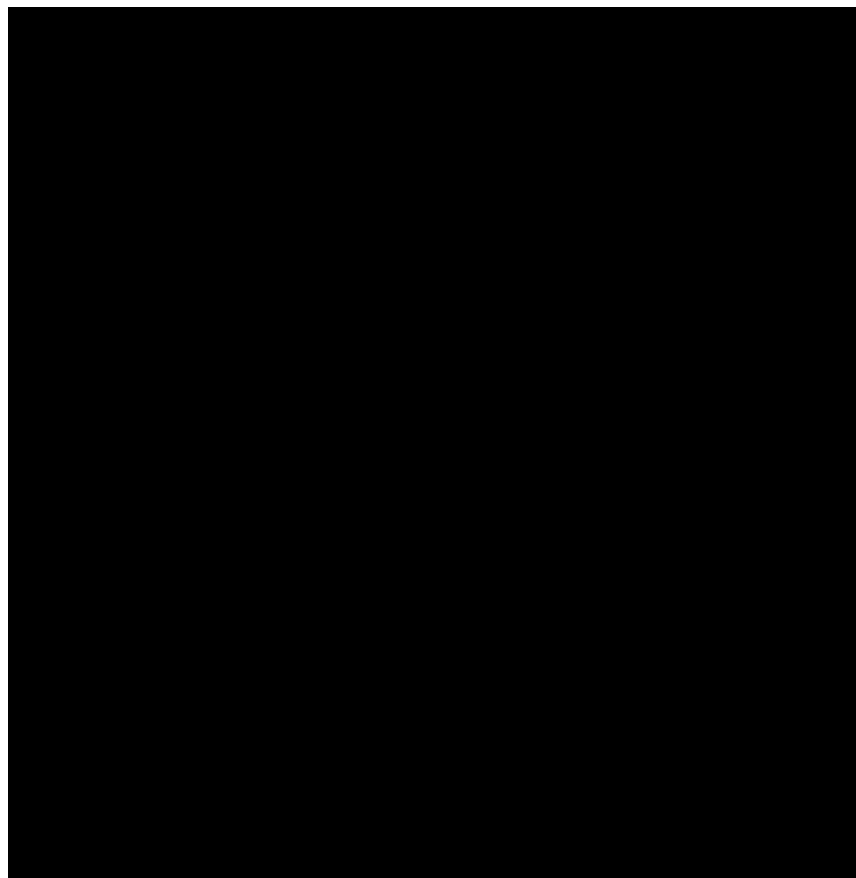- July 15, 2009 1st beam at 8id
- Nov 11, 2009 2nd beam at 8id
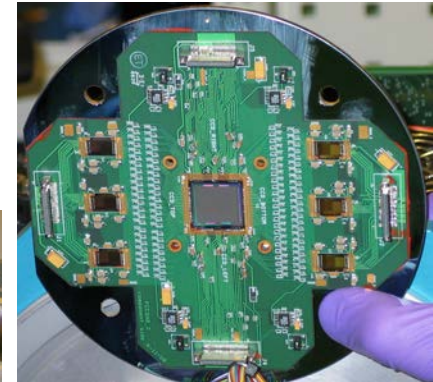
APS 480 x 480 Fast CCD Story – Improvements

- January to July 2009 - Improvements and characterizing the detector
  - Improvements
    - Improved offset oscillation seen in a series of images
    - Fixed left to right intensity variation in 2x mode
  - Characterize Detector
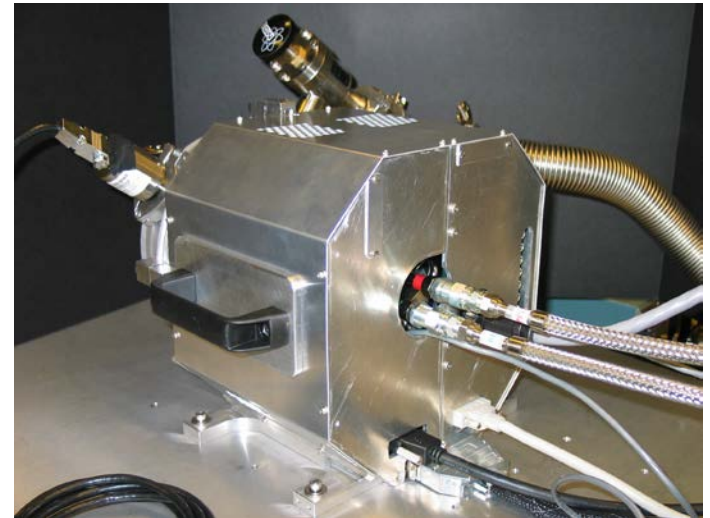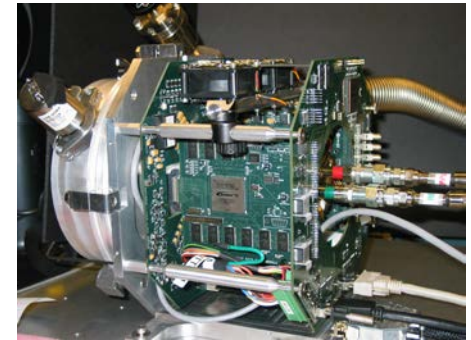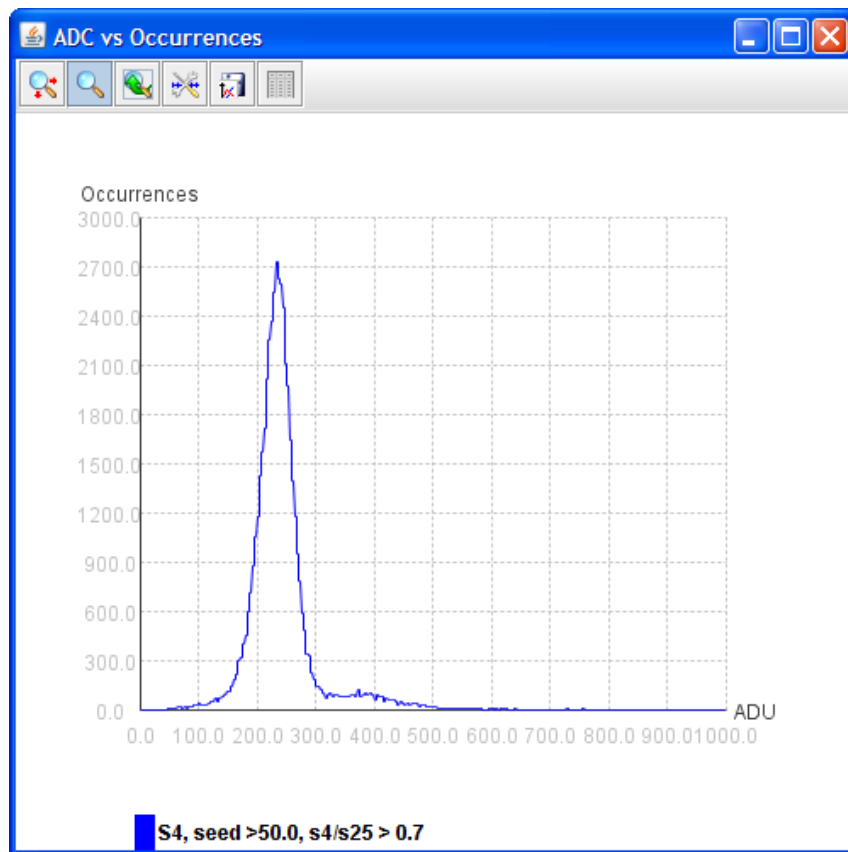
APS 480 x 480 Fast CCD Story – Science Data

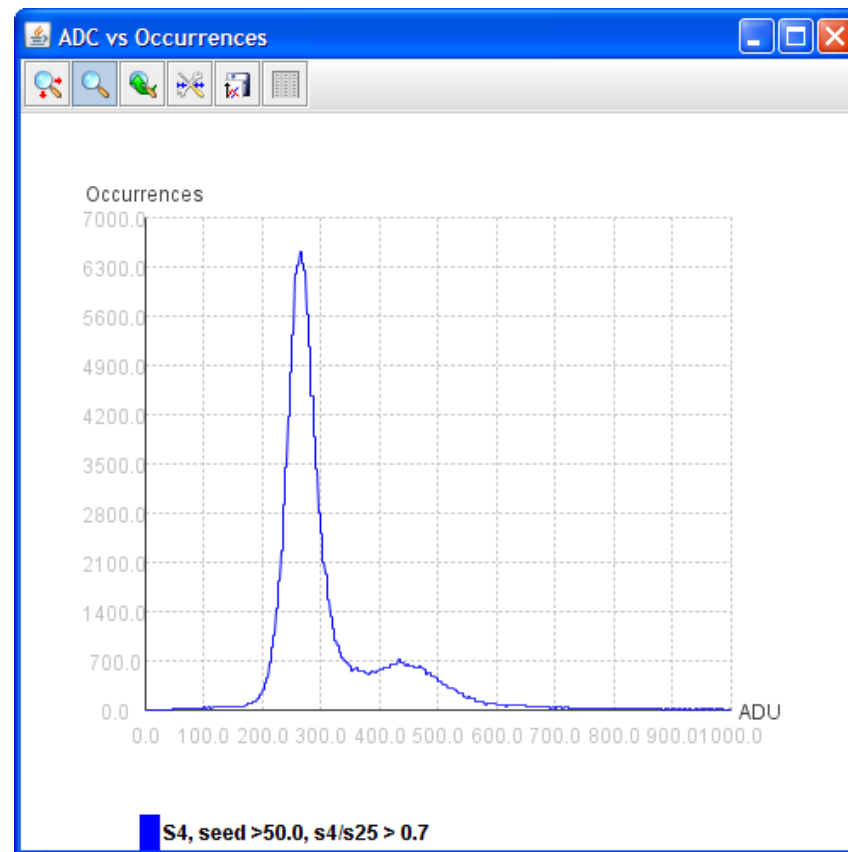ALS Fe fluorescence with 30 V Bias in 8x mode
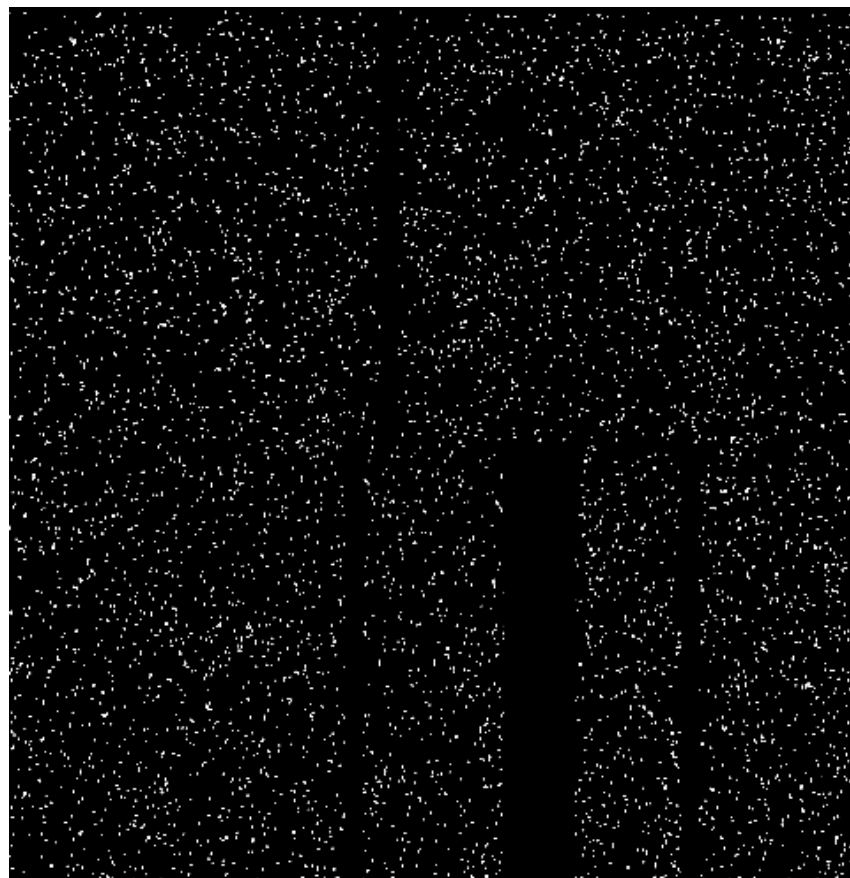
APS Fe fluorescence with 30 V Bias in 8x mode

APS 480 x 480 Fast CCD Story – Science Data

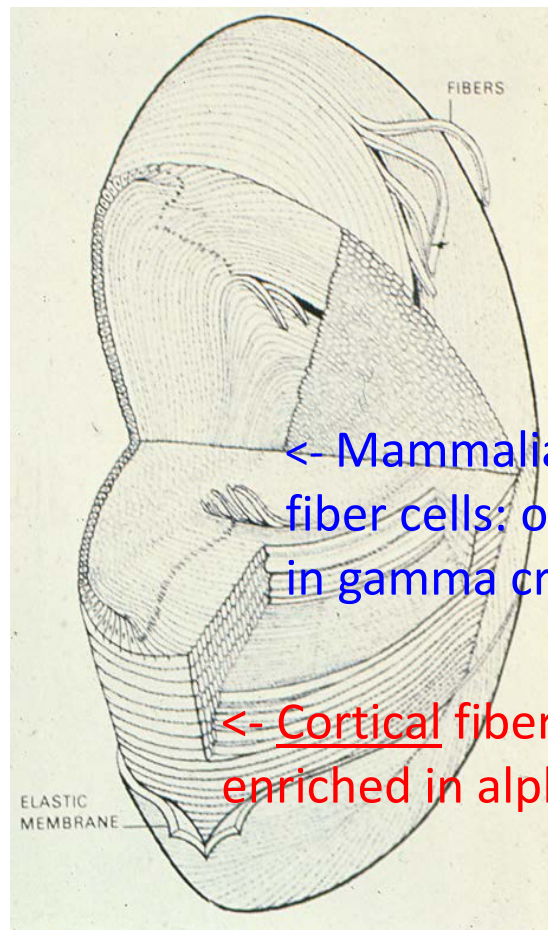Histogram of ALS fluorescence data looking at bottom ½ of CCD

Histogram of APS fluorescence data looking at bottom ½ of CCD

S4 histogram algorithm - Sums the 4 most energetic pixels in a 5x5 box around a seed pixel. Requires that 70% of the energy in the box be in the 4 most energetic pixels.

APS 480 x 480 Fast CCD Story – Science Data

**The lens contains <u>protein mixtures</u>, that vary in concentration and composition with position.**

<- Mammalian <u>nuclear</u> fiber cells: older, enriched in gamma crystallin

<- <u>Cortical</u> fiber cells: younger, enriched in alpha crystallin

FIBERS

ELASTIC MEMBRANE

β crystallin

α crystallin

nuclear fibers

cortical fibers

A

buffer

B

γ crystallin
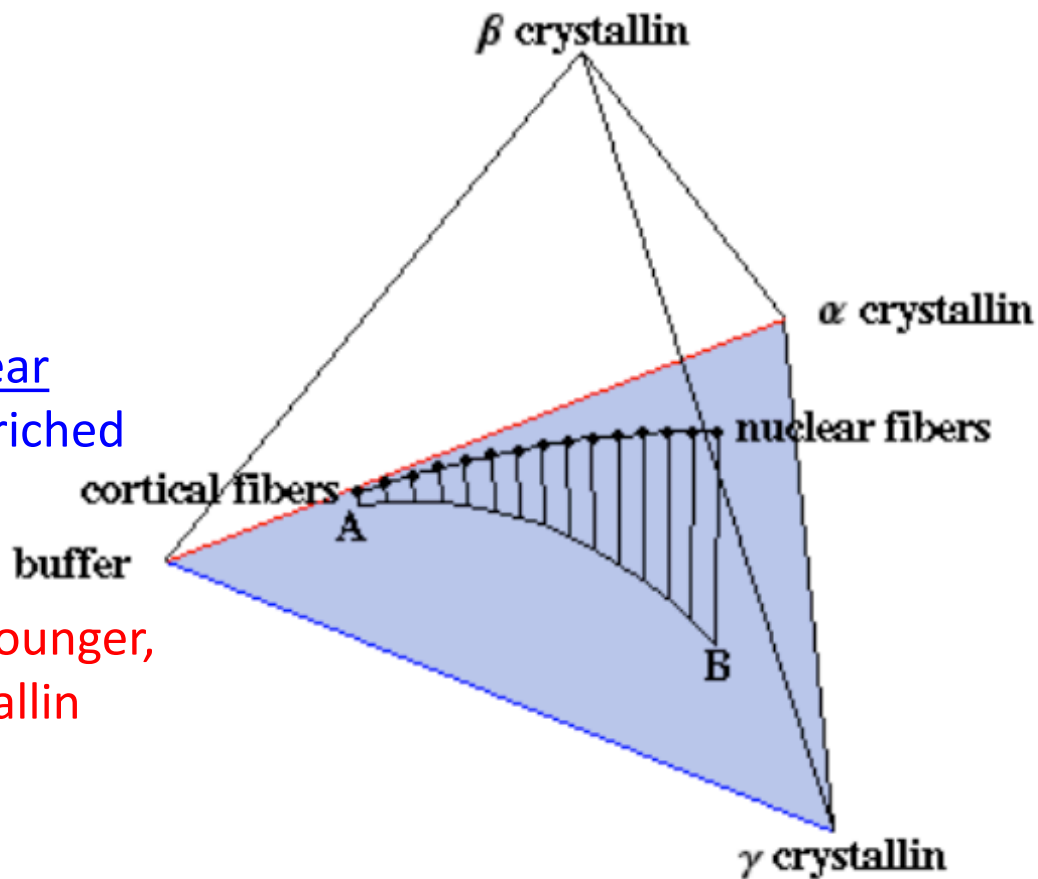
APS 480 x 480 Fast CCD Story – Science Data

Scientific Motivation for Eye-Lens Protein Studies

In a healthy eye-lens the proteins are in a mixed state which yields the optimized index of refraction profile. Changes in the phase of the eye-lens proteins can lead to various forms of eye disease.

Cold cataract is due to reversible liquid-liquid phase separation in young, mammalian eye lenses.

$T \leq T_C$

$T > T_C$

TRANSPARENT LENS

PHASE-SEPARATION (OPACITY)
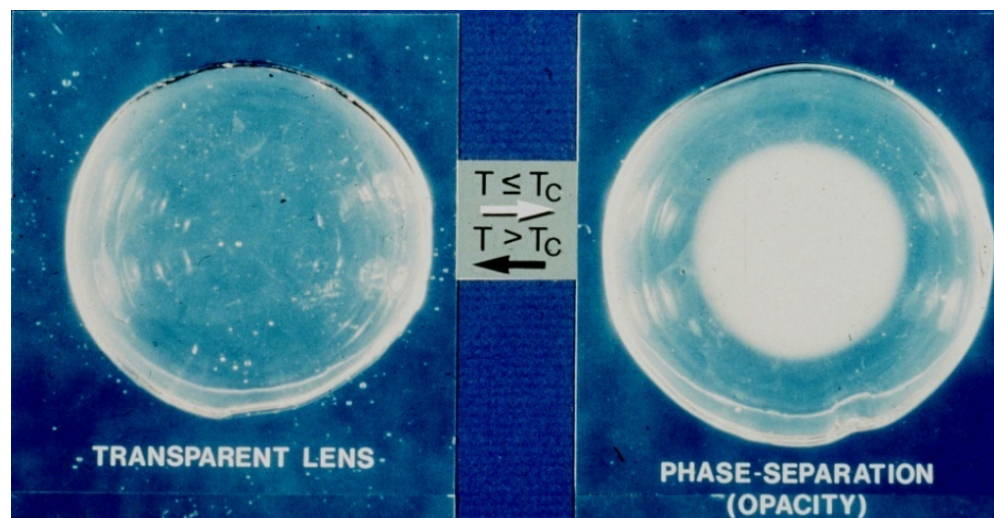
A liquid-glass transition in eye-lens protein mixtures may be related to the stiffening of the eye lens seen in presbyopia, a loss of ability to focus the eye on nearby objects

APS 480 x 480 Fast CCD Story – Science Data

X-ray Photon Correlation Spectroscopy (XPCS) can be used to measure both the structure and dynamics in mixtures of eye-lens proteins.

In the XPCS technique the sample is illuminated with a coherent x-ray beam which leads to the creation of a speckle pattern superimposed on the regular x-ray scattering pattern.

Dynamics within the sample cause the speckle pattern to fluctuate in time. Time autocorrelation of this fluctuating speckle pattern can be analyzed to yield information about the dynamics within the sample, such as localized diffusion coefficients.
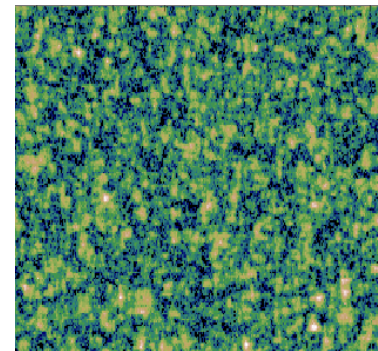
Example of a speckle pattern produced using a coherent x-ray beam. (In this case a static aerogel sample)
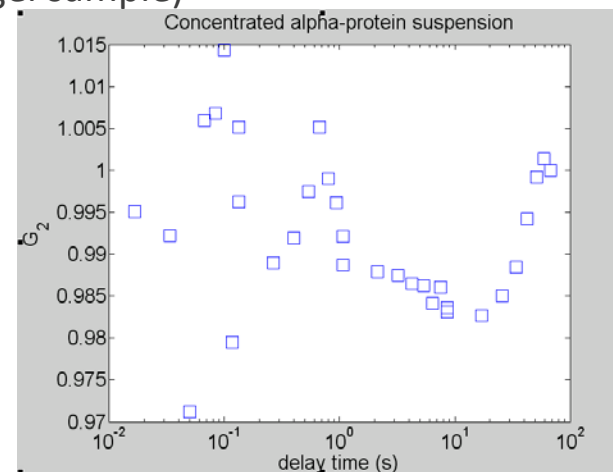
Time correlation function from a concentrated alpha crystallin suspension. For this sample the correlation function remained at 1, which means that the dynamics were too fast to be successfully resolved with the available camera.

APS 480 x 480 Fast CCD Story – Science Data
Small-Angle X-ray Scattering Results

Nuclear Homogenate
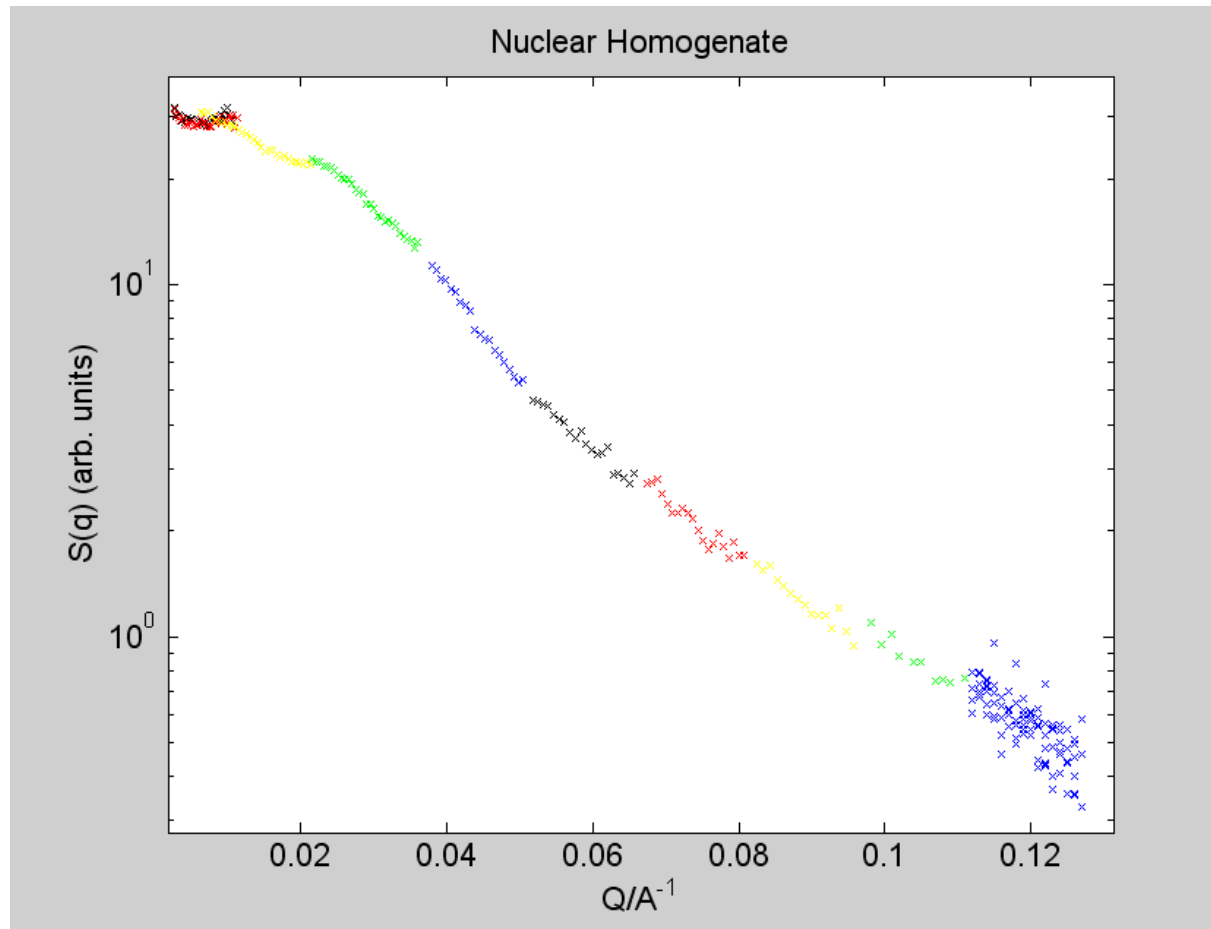
Detector Improvements - Intensity oscillation

Images taken at APS X-ray tube in building 401 – 20090115\Tiff\BeamFrof_400ms*.tif
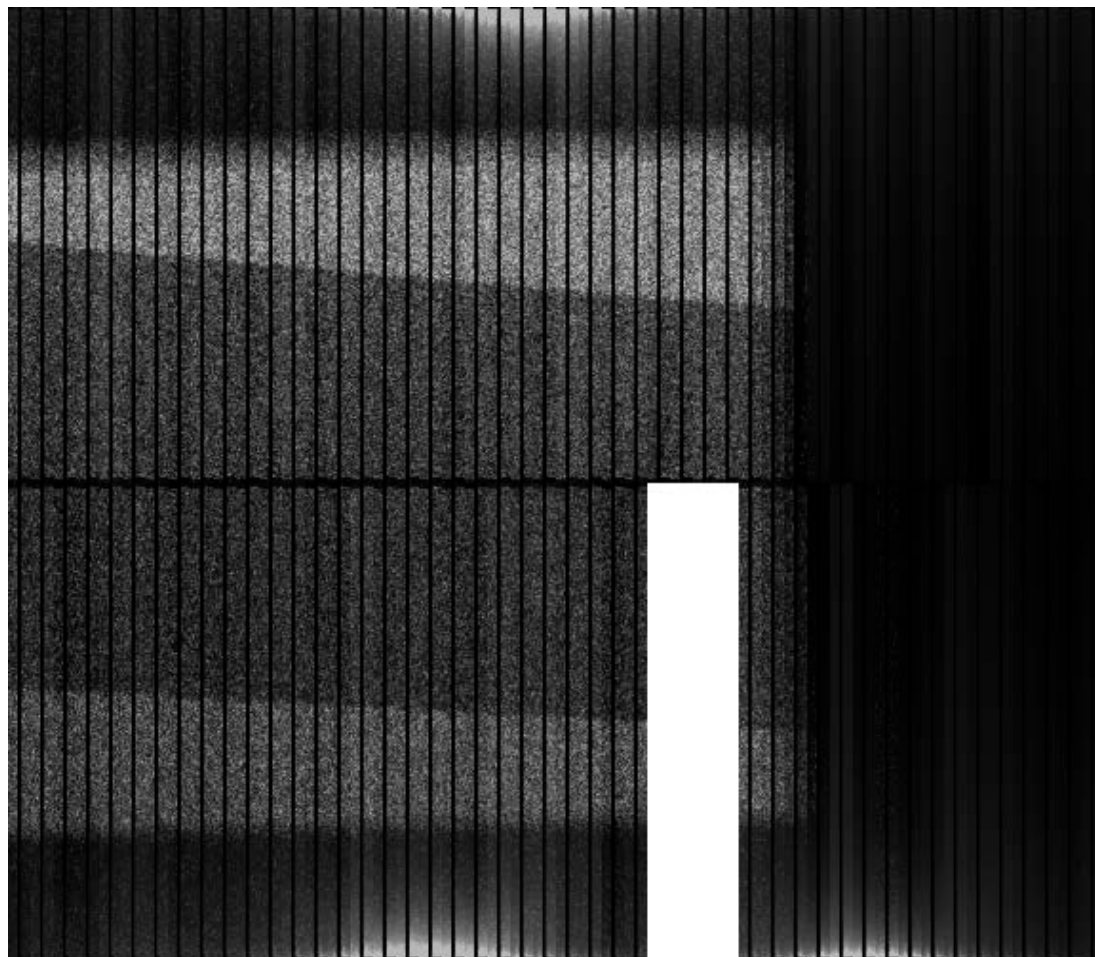
-Intensity Oscillation over whole image

-Bright rectangle is beam framed by slits

-Darker middle caused by two layers of electrical tape used to block out light

-Glow areas caused by hot spots on CCD

Detector Improvements - Intensity oscillation

- Z Projection through a single pixel over image set - 20090219-FCCD\Dark_Osc_5msec_exp-30deg*.tif files
- Pattern repeating every 8 images
- Pixels 48,255 or pixels in column 1 have the biggest oscillation around 50 ADU
- Clock Phase problem between 125MHz(8nsec) and 40MHz(25nsec)

For Pixel (45,255)
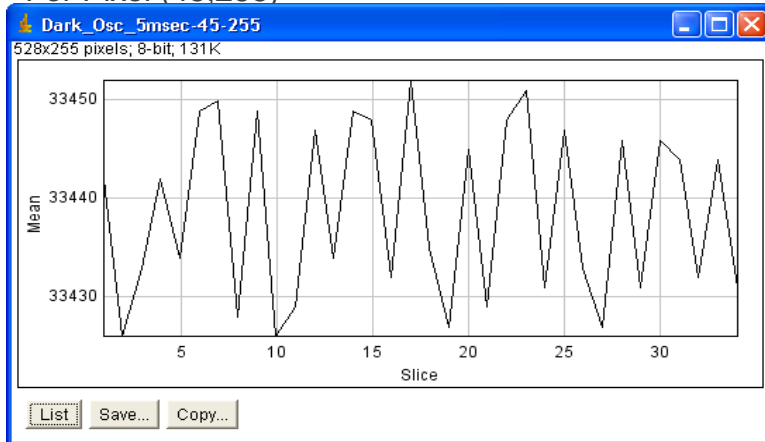
For Pixel (46,255)
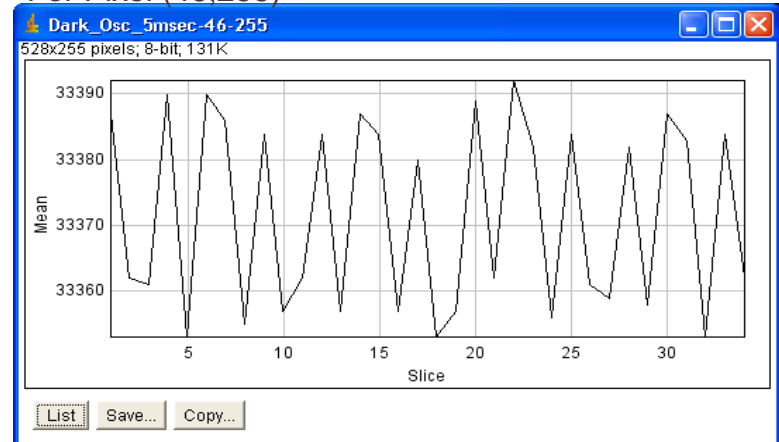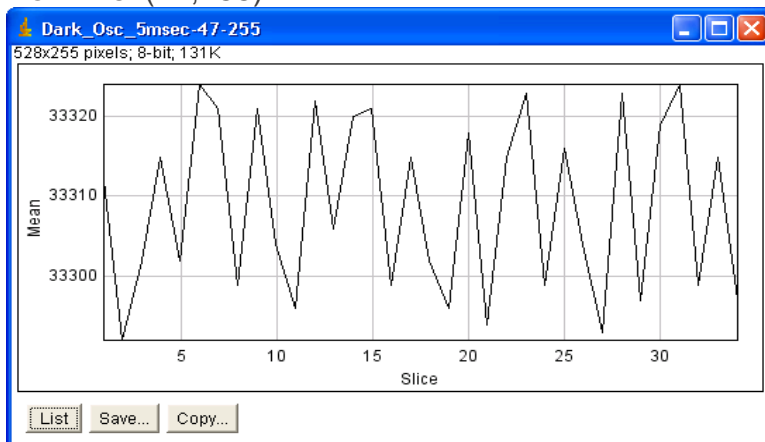
For Pixel (47,255)

For Pixel (48,255)
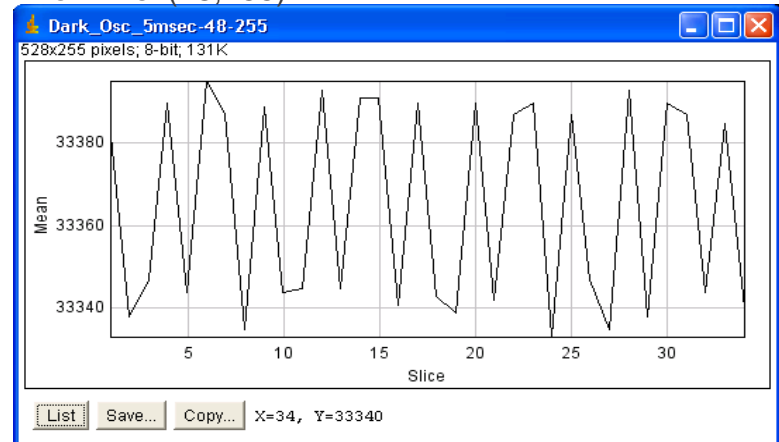
Detector Improvements - Intensity oscillation

- Original Configuration

Detector Improvements - Intensity oscillation

- Fixed on 3-02-2009 changes S2-25nsec_per_tick from 6 to 7

Detector Improvements - Intensity oscillation

- Z Projection through a single pixel over image set
  - 20090310-FCCD\DarkLightsOn-30C-10msec\DarkLightsOn_10msecE_1sE-30C*.tif files
- Cannot see a pattern
- Column 1 went from around a 50ADU oscillation to around a 10 ADU oscillation

For Pixel (45,255)
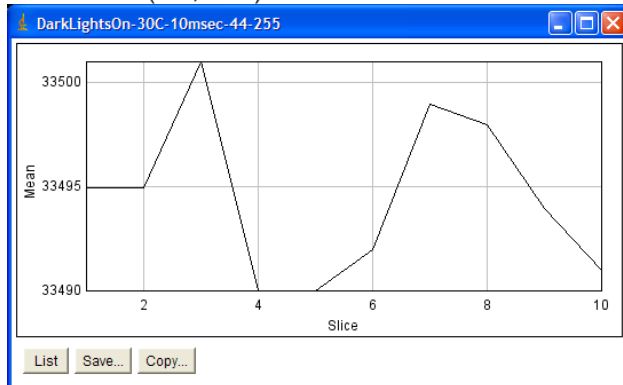
For Pixel (46,255)
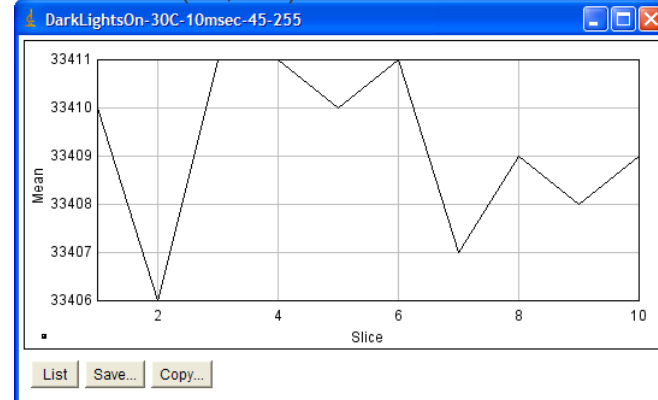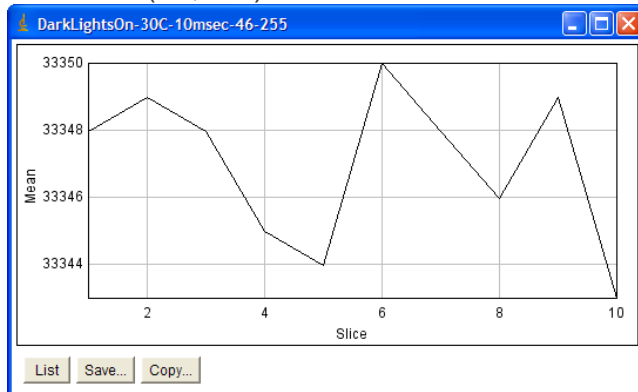
For Pixel (47,255)

For Pixel (48,255)
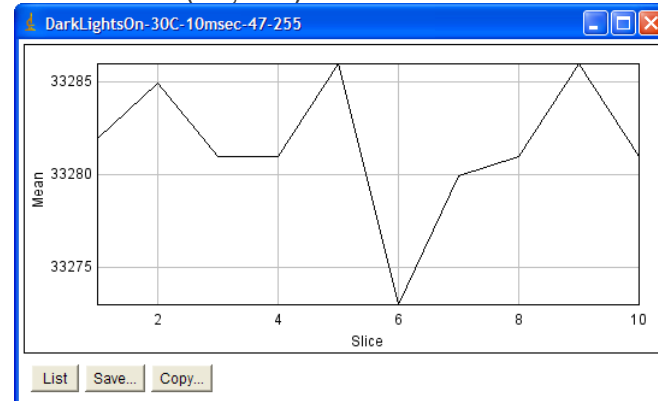
Detector Improvements - Right to Left Intensity variation

- Over scan removed between every 10 columns
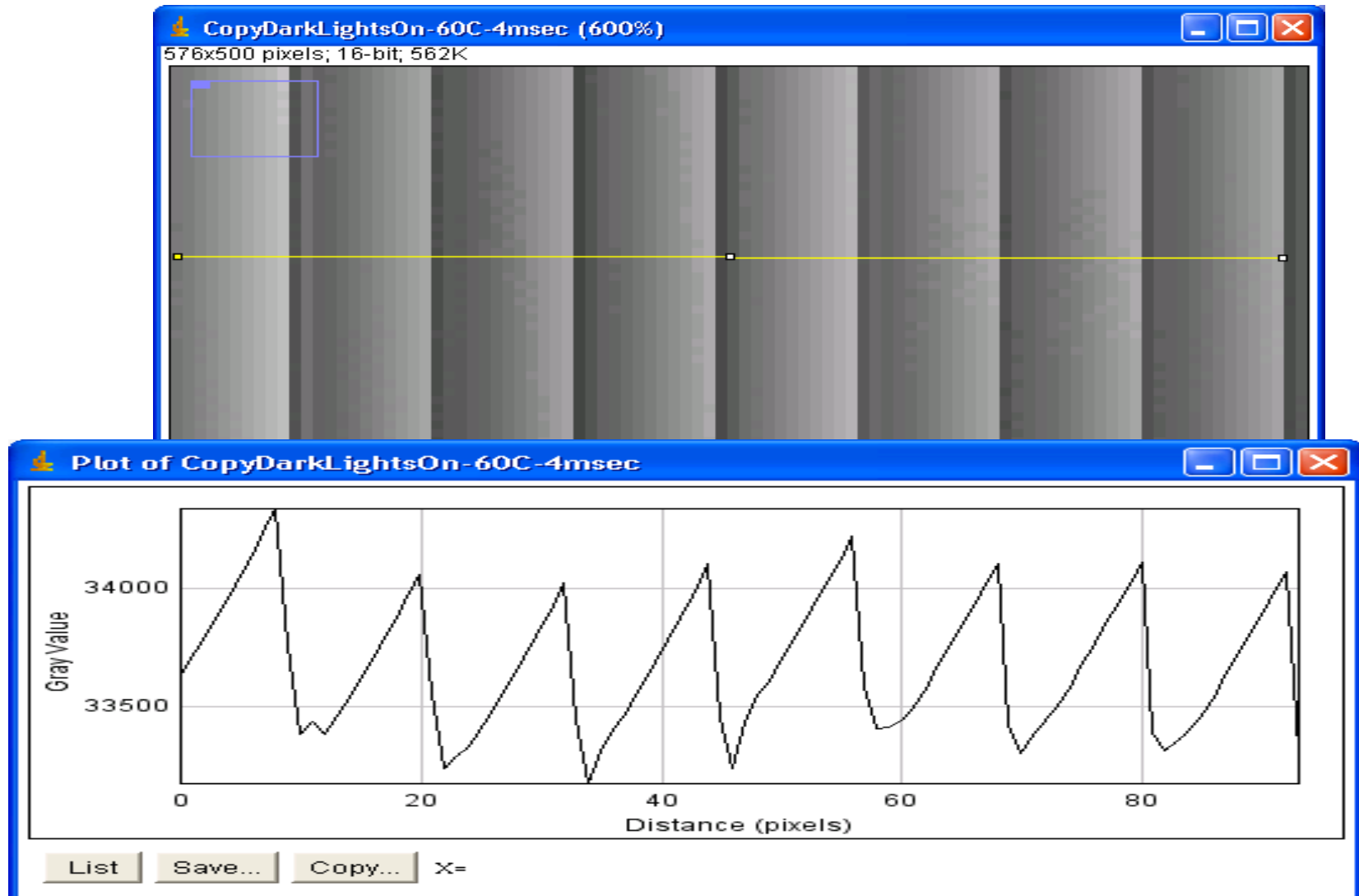
Detector Improvements - Right to Left Intensity variation

- Photon Transfer Curve
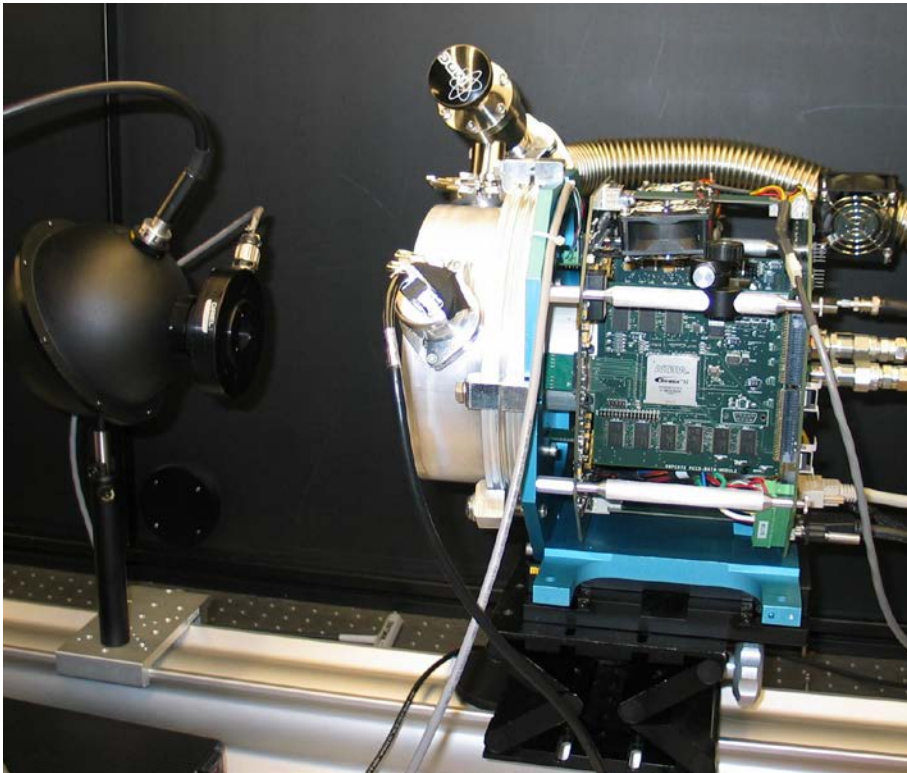
Fast CCD Detector with integrating sphere

Movie of photon transfer curve Data Set
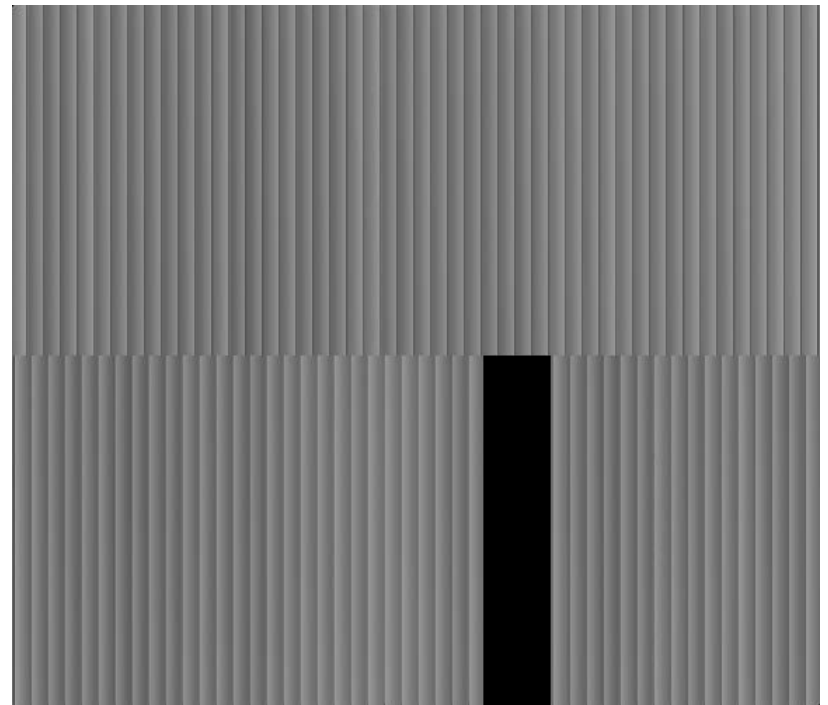
Detector Improvements - Right to Left Intensity variation

- Photon Transfer Curve
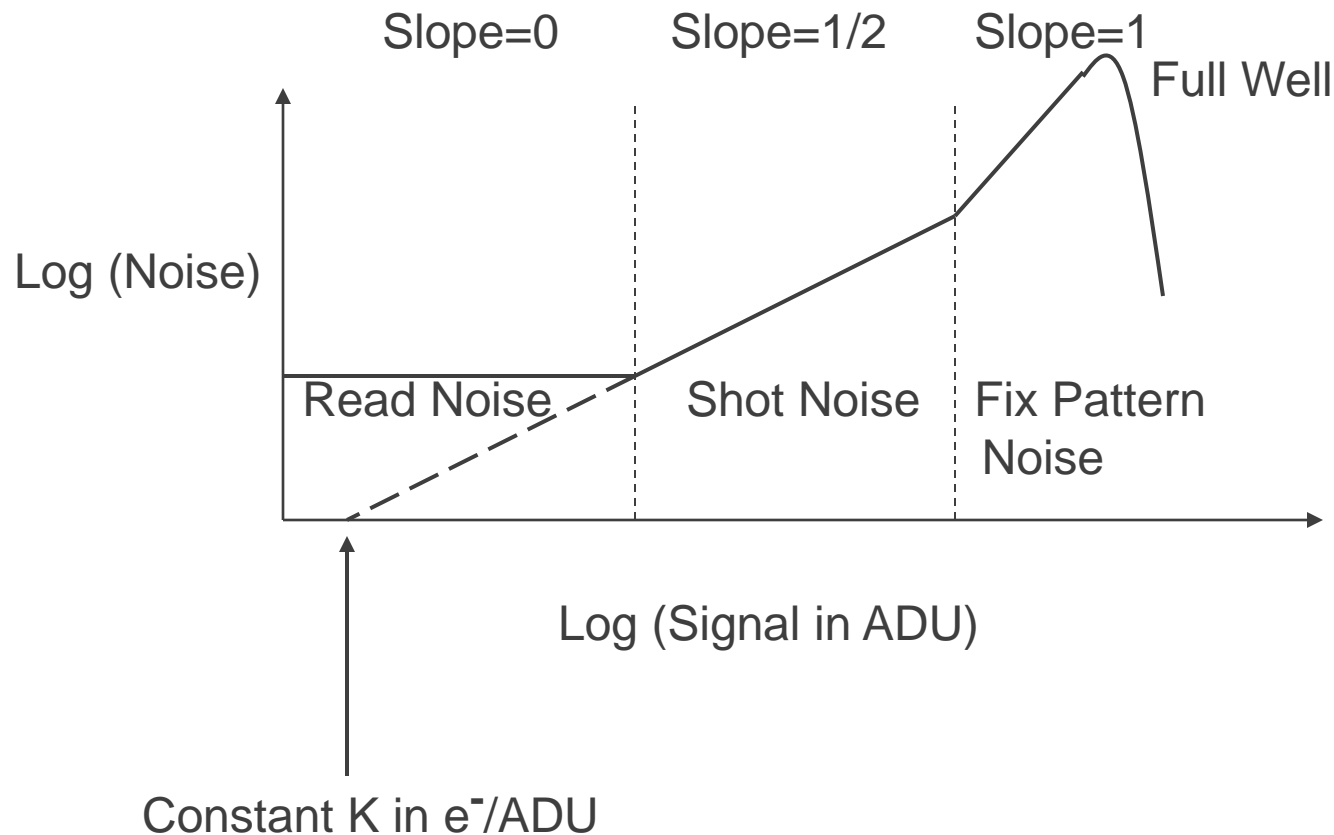
From: Scientific Charge-Coupled Devices
By James R. Janesick

Detector Improvements - Right to Left Intensity variation

- Photon Transfer Curves Variation from Column 1 to Column 10
- Spent long time with analysis
- Eventually moved on to test out 8x mode
  - 8x mode didn't have the right to left intensity variation!
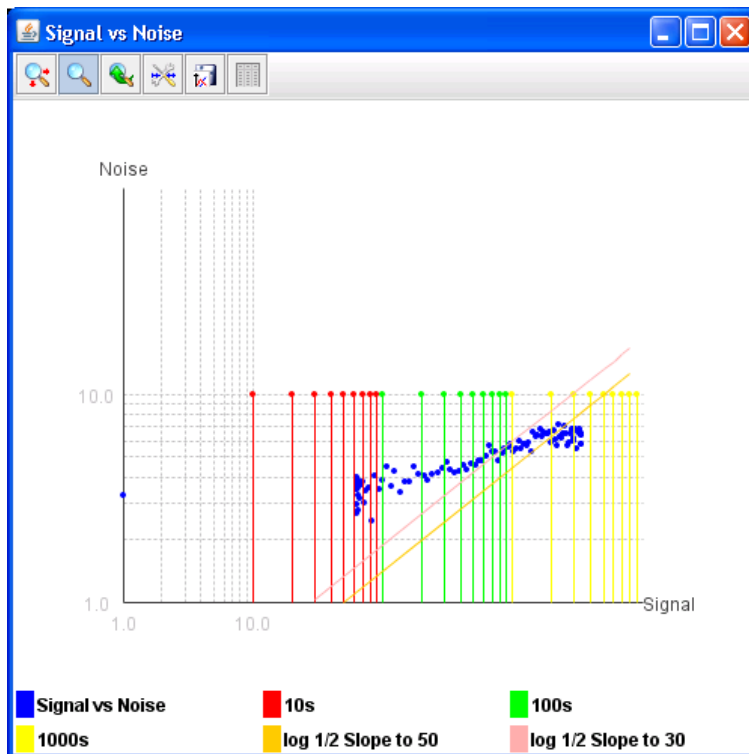
Column 1
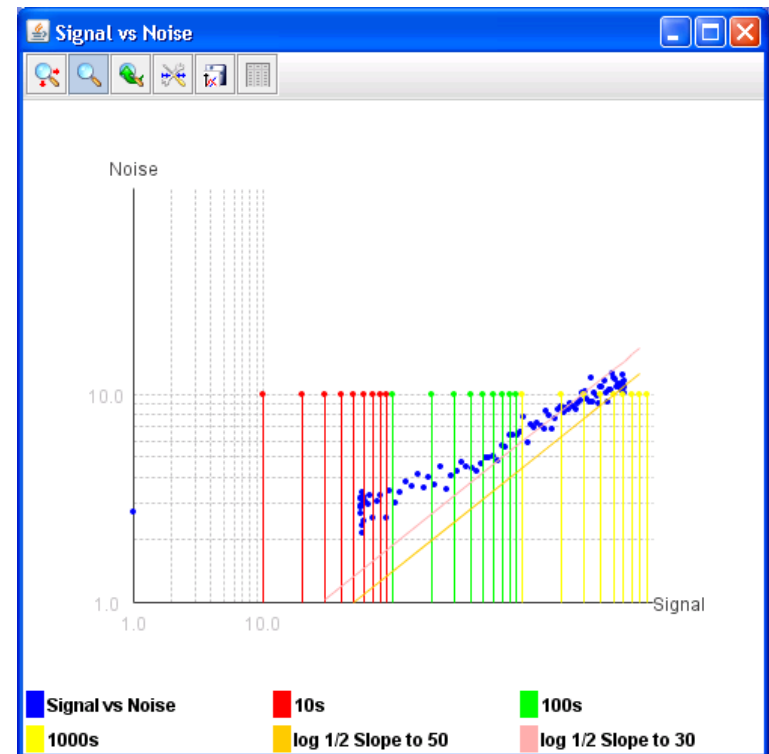
Column 10

Detector Improvements - Right to Left Intensity variation

- Made configuration of 2x Mode like 8x mode on 4-07-09
  - Changed "25nsec_per_tick" in S3, S5, and S6 from 03 to 04
    - S3 = horizontal read, convert and save data
    - S5 = horizontal read, convert and don't save data (flush fCRIC pipe)
    - S6 = horizontal read, convert and save data (flush finished)
  - S5 "passes_per_state" changed from 7 to 6
  - S6 "passes_per_state" changed from 5 to 6
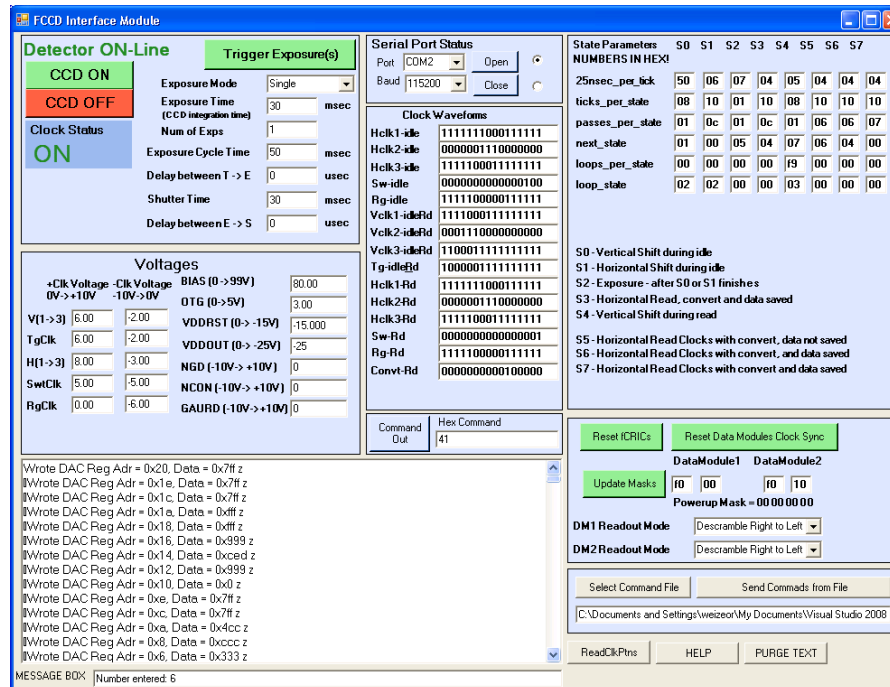
Detector Improvements - New 2x Configuration
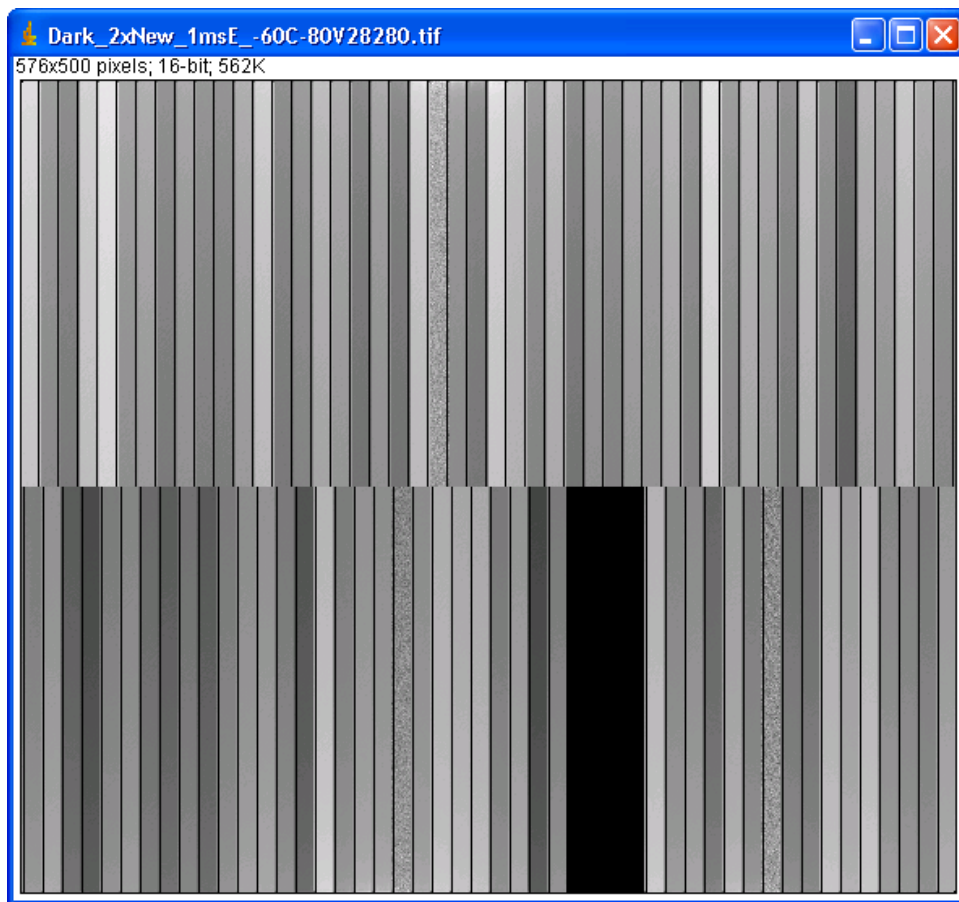
Dark image with new
2x configuration

Detector Improvements - New 2x Configuration
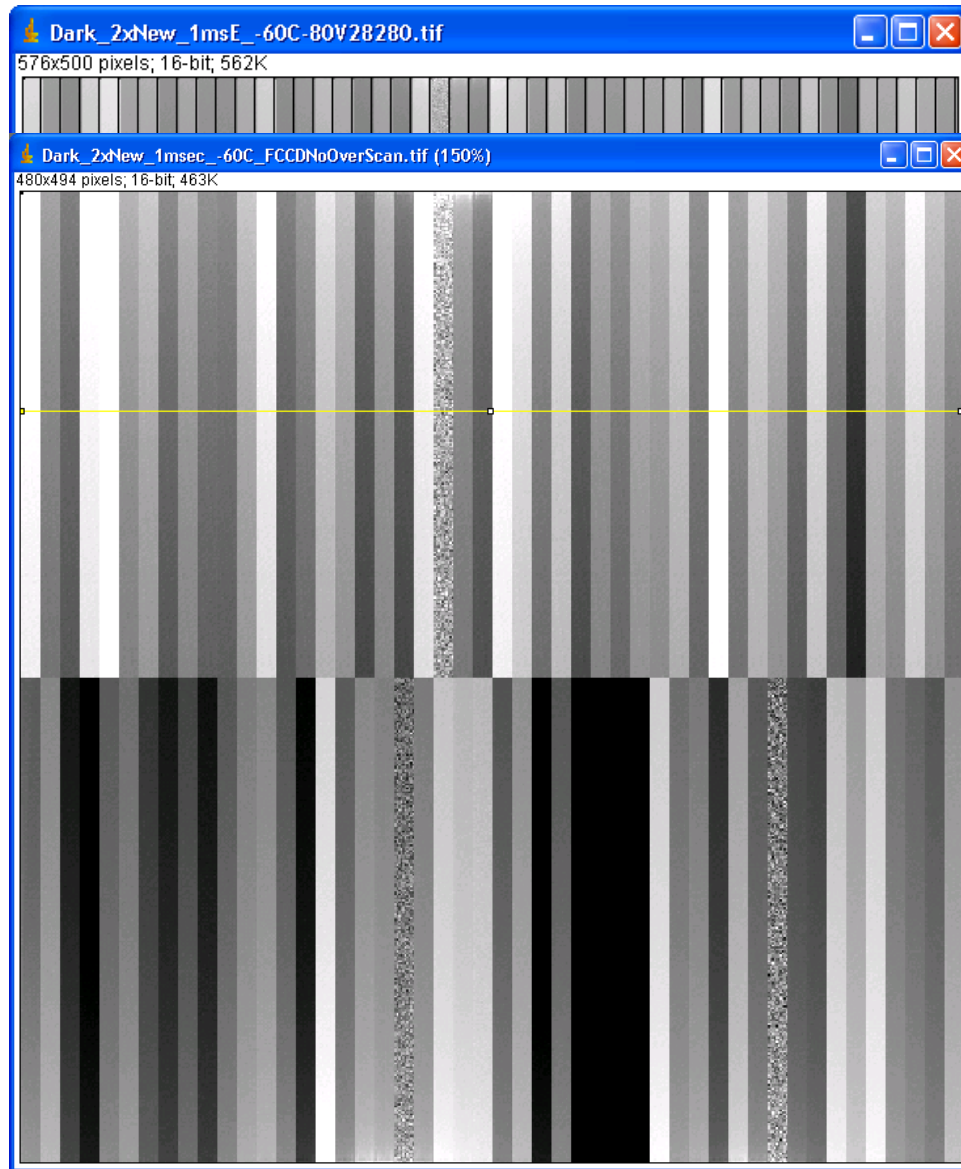
Dark image with new
2x configuration

Same image
-Over Scan Removed
-B&C adjusted

J. Weizeorick - XSD-BTS Group - 2009 Advanced Light Source Users' Meeting - October 15-17, 2009

Detector Improvements - New 2x Configuration

Dark image with new 2x configuration

Same image
-Over Scan Removed
-B&C adjusted
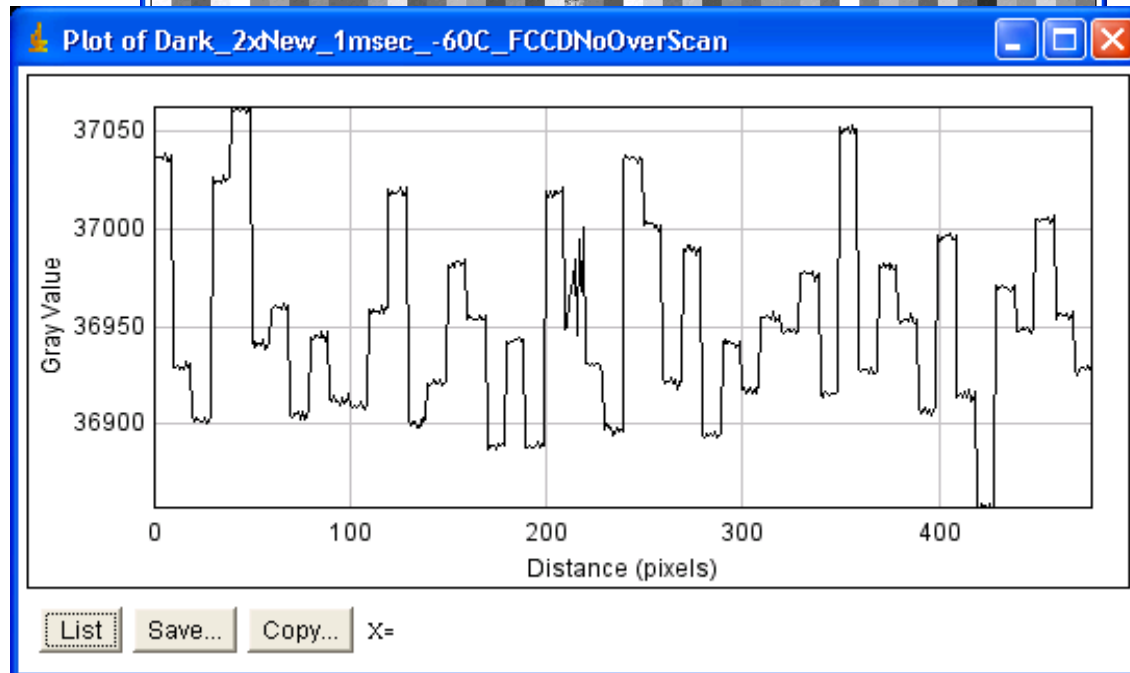
Horizontal cut of image

Detector Improvements – New 2x Configuration

- Photon Transfer Curves Same for Column 1 to Column 10

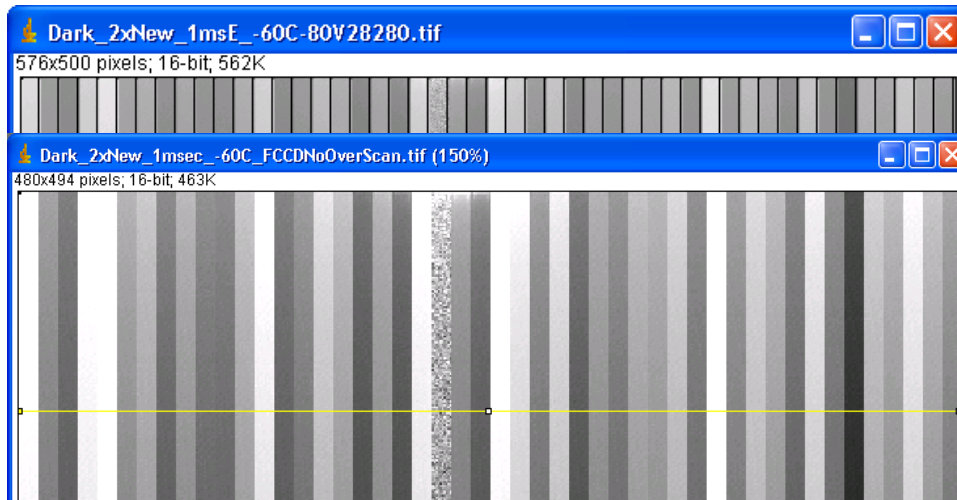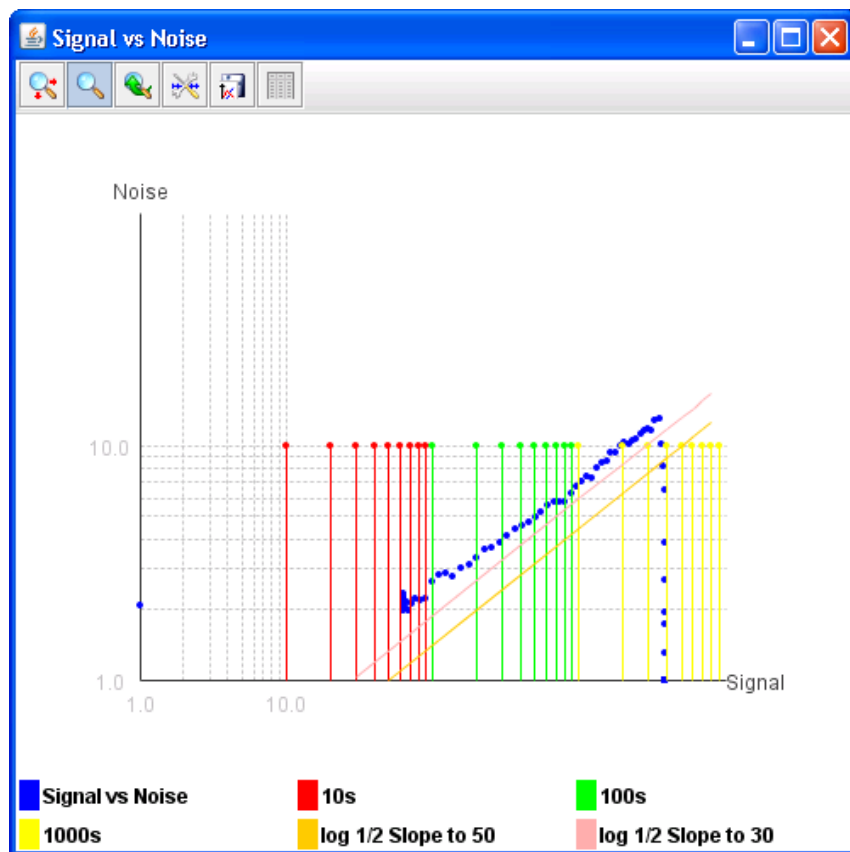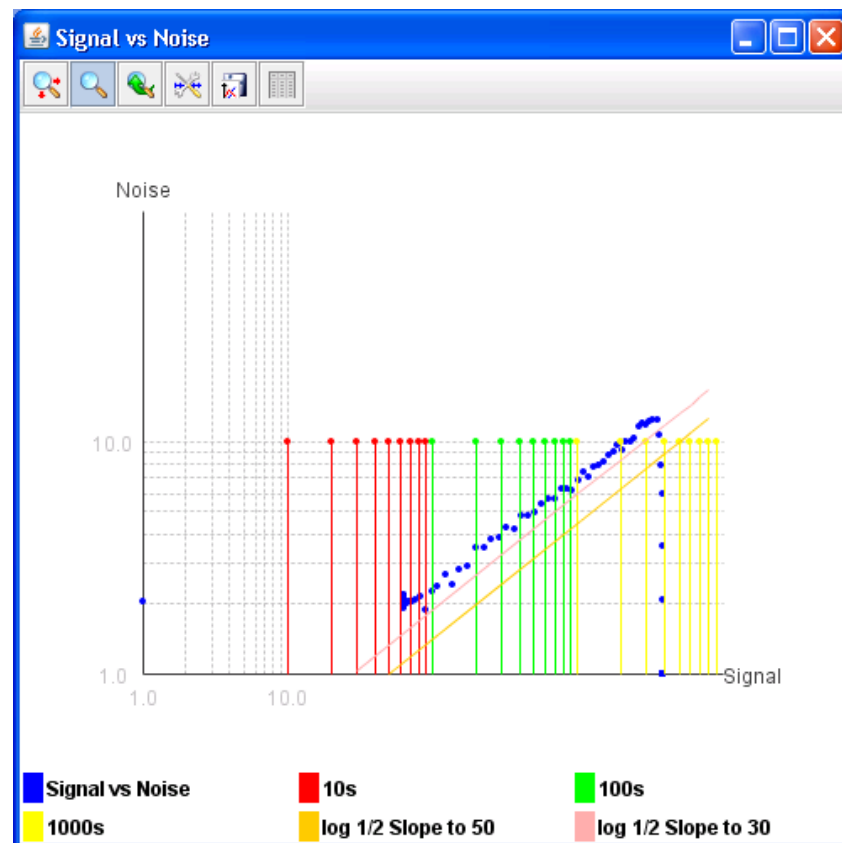Column 1   Column 10

APS 480 x 480 Fast CCD Story - Detector Specifications

- 480 x 480 Pixels
- 30 x 30 μm pixels size
- 125 Frames Per Second
- 5.1 msec readout

14.4 mm x 14.4 mm CCD area
Closed-cycle refrigeration
Detector head = 40 lbs
Dark at 30V and -60°C is .073 ADU/msec
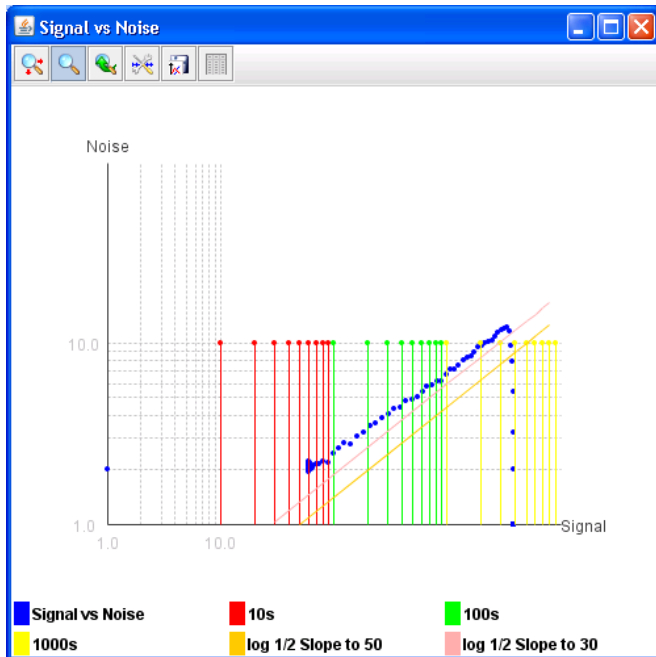
2x Mode Photon Transfer Curve

- Read Noise = 2 ADU
- K constant = 24 e-h/ADU = 87 eV/ADU
- Full Well = 4000 ADU

8x Mode Photon Transfer Curve

- Read Noise = 7 ADU
- K constant = 6 e-h/ADU = 22 eV/ADU
- Full Well = 3500 ADU

APS 480 x 480 Fast CCD Story – Future Tasks and Goals

- Convert GUI Software to EPICS Area Detector Software
  - Will allow spec to modify parameters through EPICS Channel Access
- Beam time at 8id on November 11, 2009
- Build more 480 x 480 Fast CCD Detector (1 at APS, 2 at ALS)
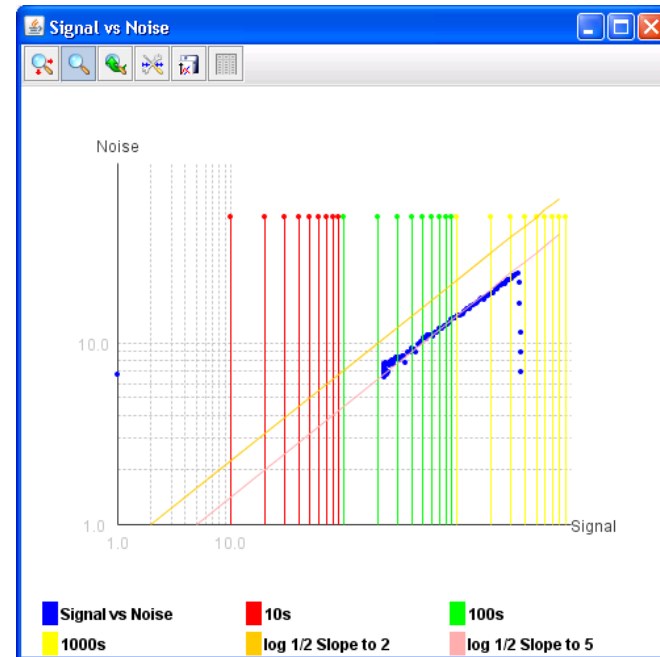 - Build 4 more covers   (1 for APS, 3 for ALS)
  - Test 3 Power Supplies   (1 for APS, 2 for ALS)
  - Test out 3 Sets of Back End Electronics   (1 set for APS, 2 sets for ALS)
- Maximize Frame Rate
  - Try fCRICs with faster ADC conversion time
    - Currently at 1.6usec per conversion which gives a 5.1msec readout
    - Would like to run fCRIC 1.0 usec per conversion or faster
  - Move system to Coreco X64 Xcelera-CL PX4 Frame Grabber
    - Uses XP 64 bit
    - Uses PCI Express x4 or x8 slot
    - Will allow us to increase frames per second for longer burst
  - Add faster Hard Drivers (Raid Array..) to maximize continuous frames per second
  - Try on-board background subtraction
  - Try on-board threshold data reduction

Future of Fast CCD Detectors at ANL

- Building a 1k x 1k Frame Transfer Fast CCD
  - Using ARRA Funds
  - 2.5 Years to complete
  - Dedicated Wafer Run at Dalsa using LBNL's CCD Design
  - Using LBNL's fCRIC Chips
  - Scientist Requirements
    - Frame transfer
    - Smaller and lighter detector head, < 8 kg
    - Size of detector head < 200mm x 200mm x 200mm
    - Digitization >= 1MHz
   - On-board threshold and data compression

The End

Extra Slides

The APS Detector Pool – Recent Additions

- Pilatus 100K digital Si pixel array detector developed at the Swiss Light Source/PSI (http://pilatus.web.psi.ch/pilatus.htm)

- a-Si flat panel detector (GE Healthcare; Perkin Elmer)
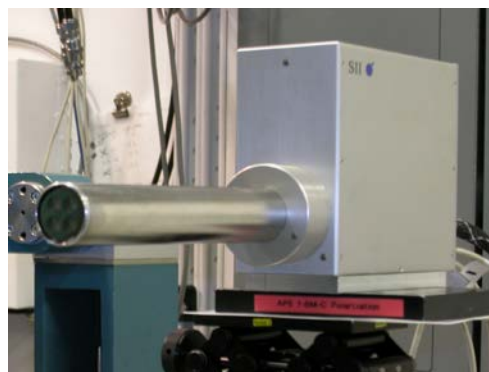
- 4-element Si drift detector array (SII NanoTechnology)

a-Si flat panel detector (GE Healthcare; XSD-BTS contact: J. Lee)

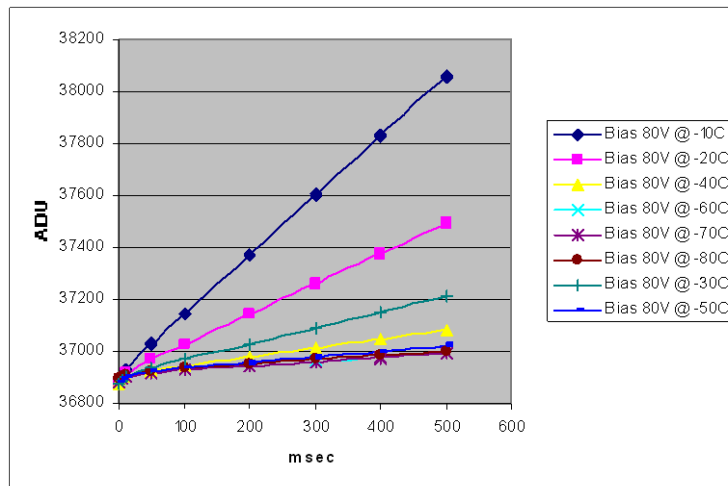Pilatus 100K digital Si pixel array detector (SLS/PSI; XSD-BTS contact: A. Miceli)
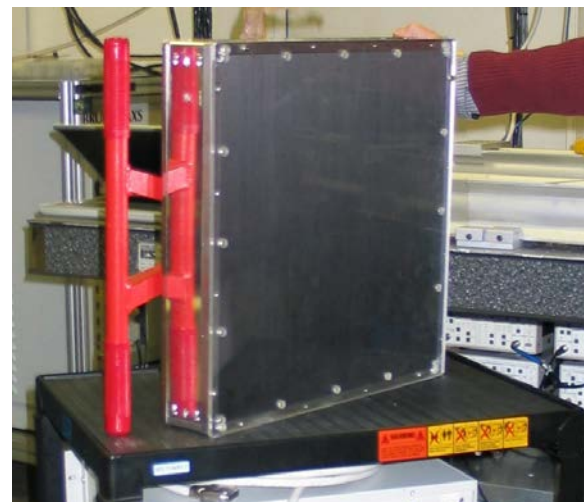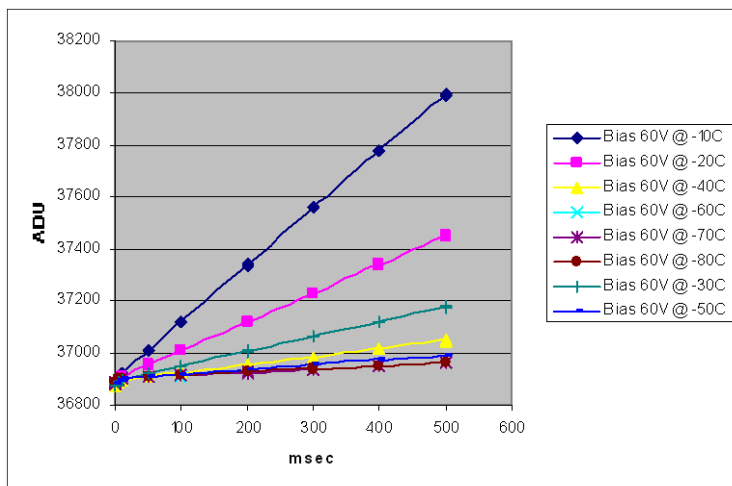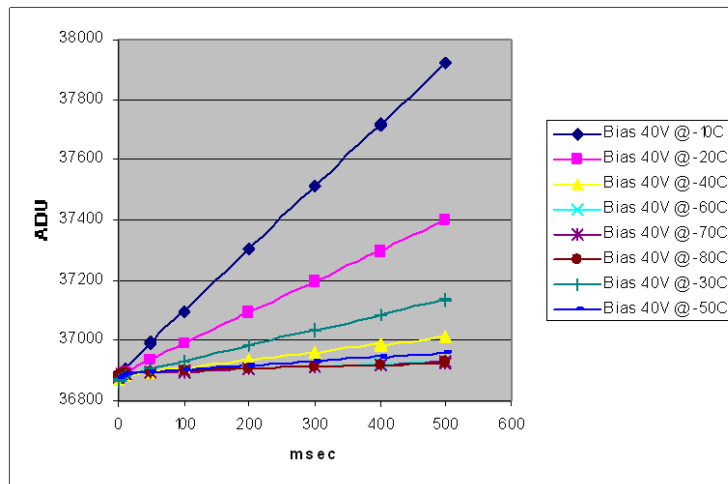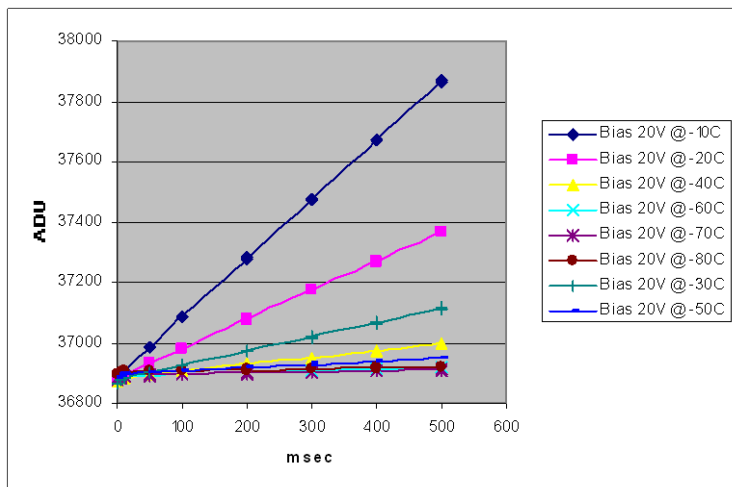
4-element Si drift detector array (SII NanoTechnology; XSD-BTS contact: A. Miceli)

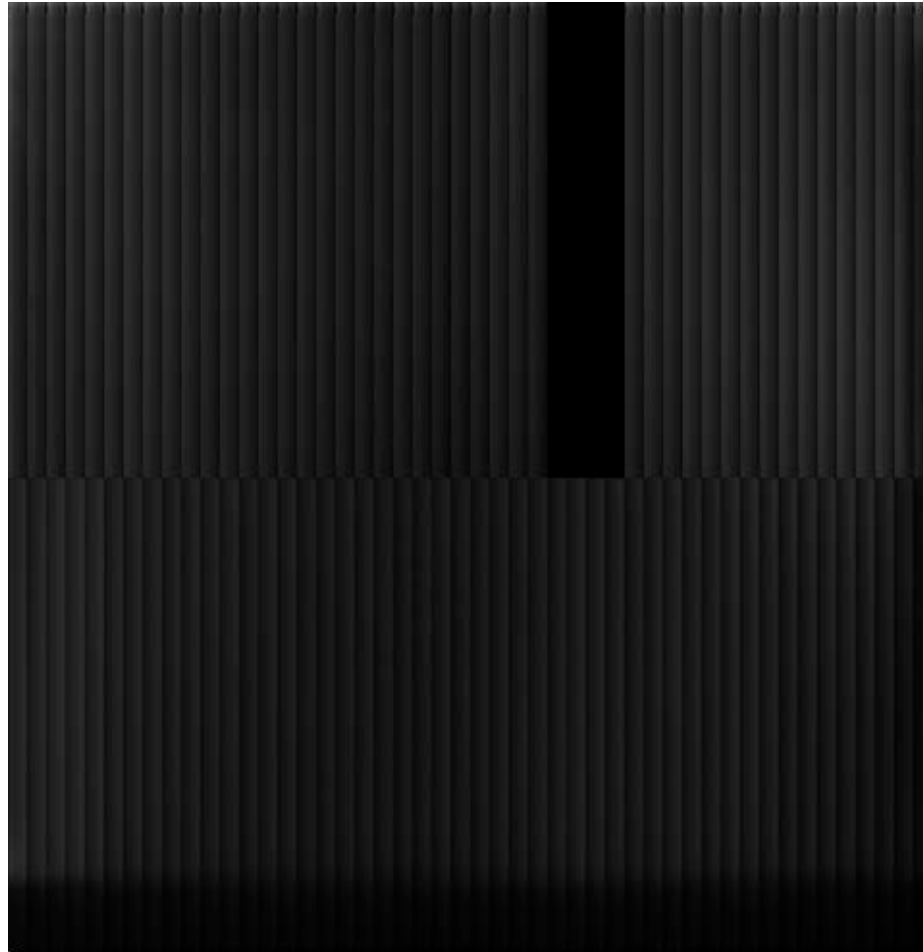# Same Photon transfer, but use image with same exposure as photon transfer images for average offset value.
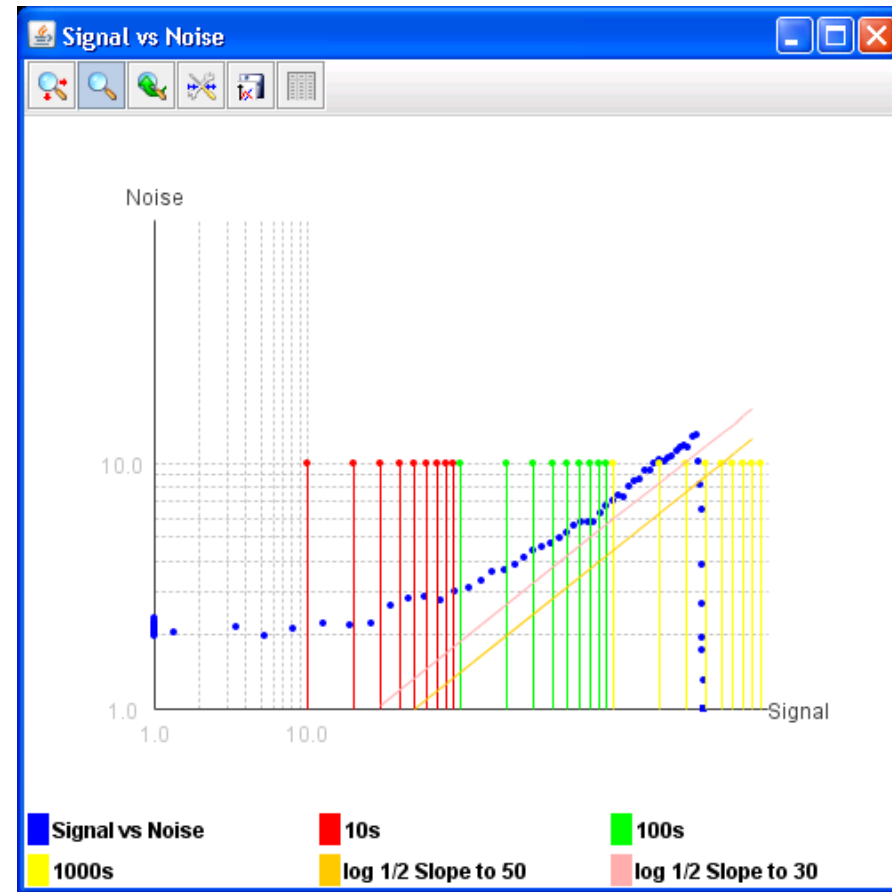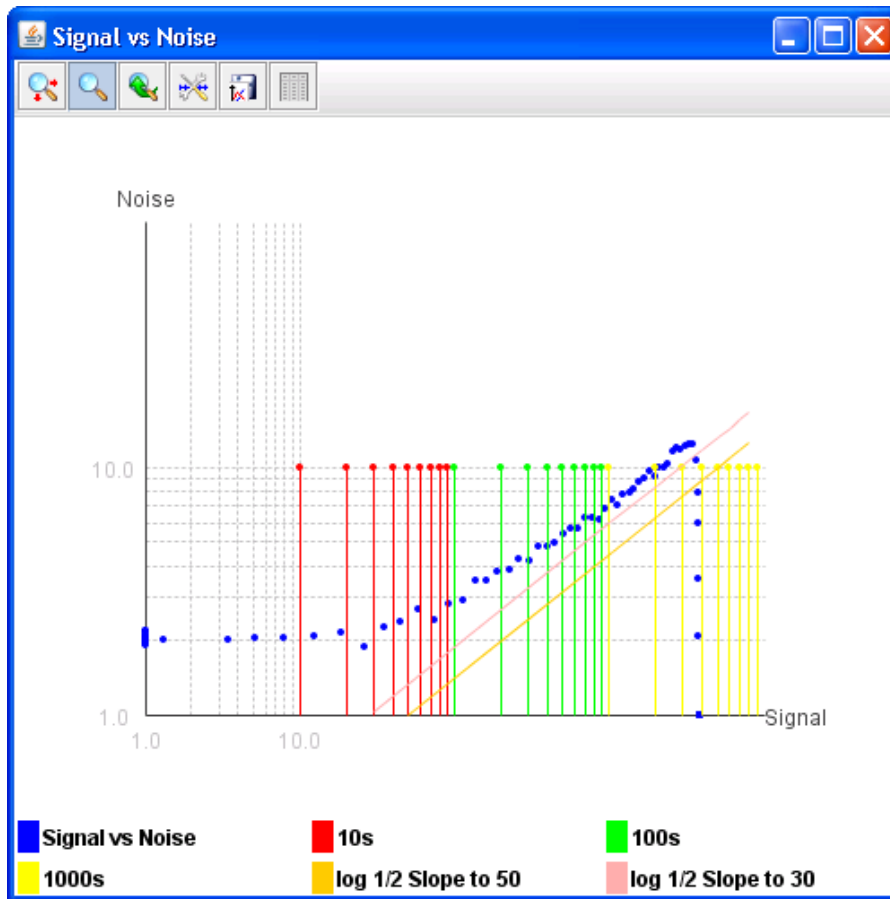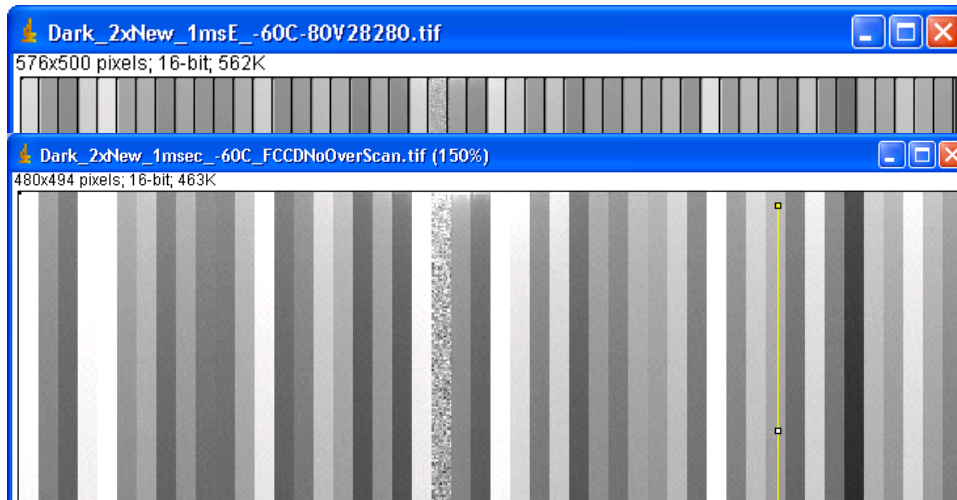
Dark Current Data
at different Currents and Temperatures in 2x Mode

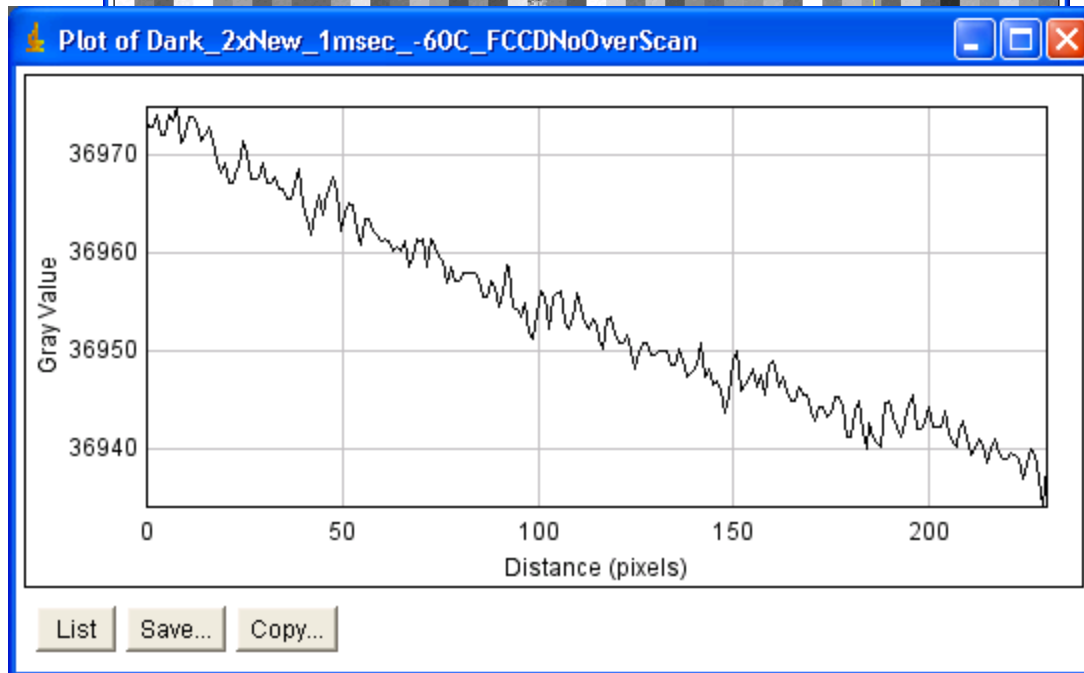# Detector Improvements - Right to Left Intensity variation

Detector Improvements - New 2x Configuration

Dark image with new 2x configuration

Same image
-Over Scan Removed
-B&C adjusted

Vertical cut of image top to bottom

Scientific Motivation for Eye-Lens Protein Studies

•Understanding the glass transition in eye-lens protein mixtures will shed light on related physiological issues : in particular the stiffening of the eye lens seen in presbyopia, a loss of ability to focus the eye on nearby objects.

•Dynamic light scattering using lasers has measured a slowing down of long wavelength dynamics in mixtures of eye-lens proteins. However, DLS cannot see the protein-protein nearest neighbor peak, which should be the most sensitive to the onset of a glass transition.

•X-ray Photon Correlation Spectroscopy (XPCS) can be used to measure dynamics near this peak in concentrated suspensions. However, XPCS measurements on protein suspensions are extremely challenging due to fast dynamics and x-ray damage.

• The optimal camera for such experiments needs to work at high energy (to avoid x-ray damage to the proteins), have high efficiency (to make up for low signal) and have very fast readout (to maximize the range of time scales that can be

APS 480 x 480 Fast CCD Story – Science Data

Photon Droplet Binning - 11.5 keV